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WPI, INSPEC

(54) Cooling compressor motor

(57) When a compressor has raised the pressure of a fluid, it can be switched to either "idle" or "off". "Off" uses less power than "idle", but repeated switching "off" and "on" can cause the compressor motor 17 to overheat. The control 14, 15 therefore senses pressure 11 and temperature 10, and decides whether to switch the compressor to "off" or "idle" on the basis of the temperature of the motor (either present or predicted at the time when it will need next to be switched "on") so that "off" is selected if the motor will not overheat when next switched "on" and "idle" is selected otherwise. A cooling fan 18 may be provided to accelerate cooling of the motor 17.

Fig. 4

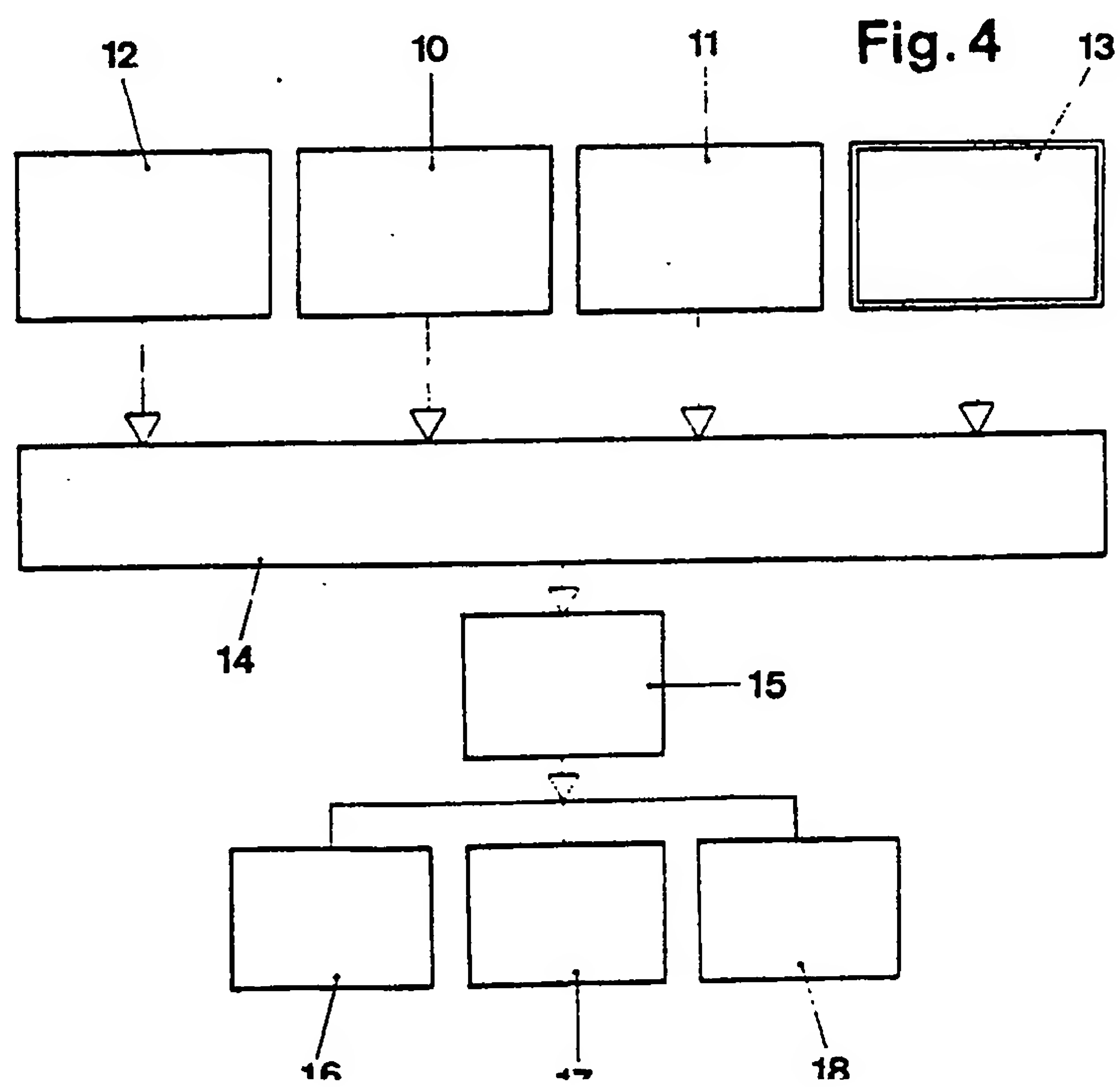

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Fig. 1

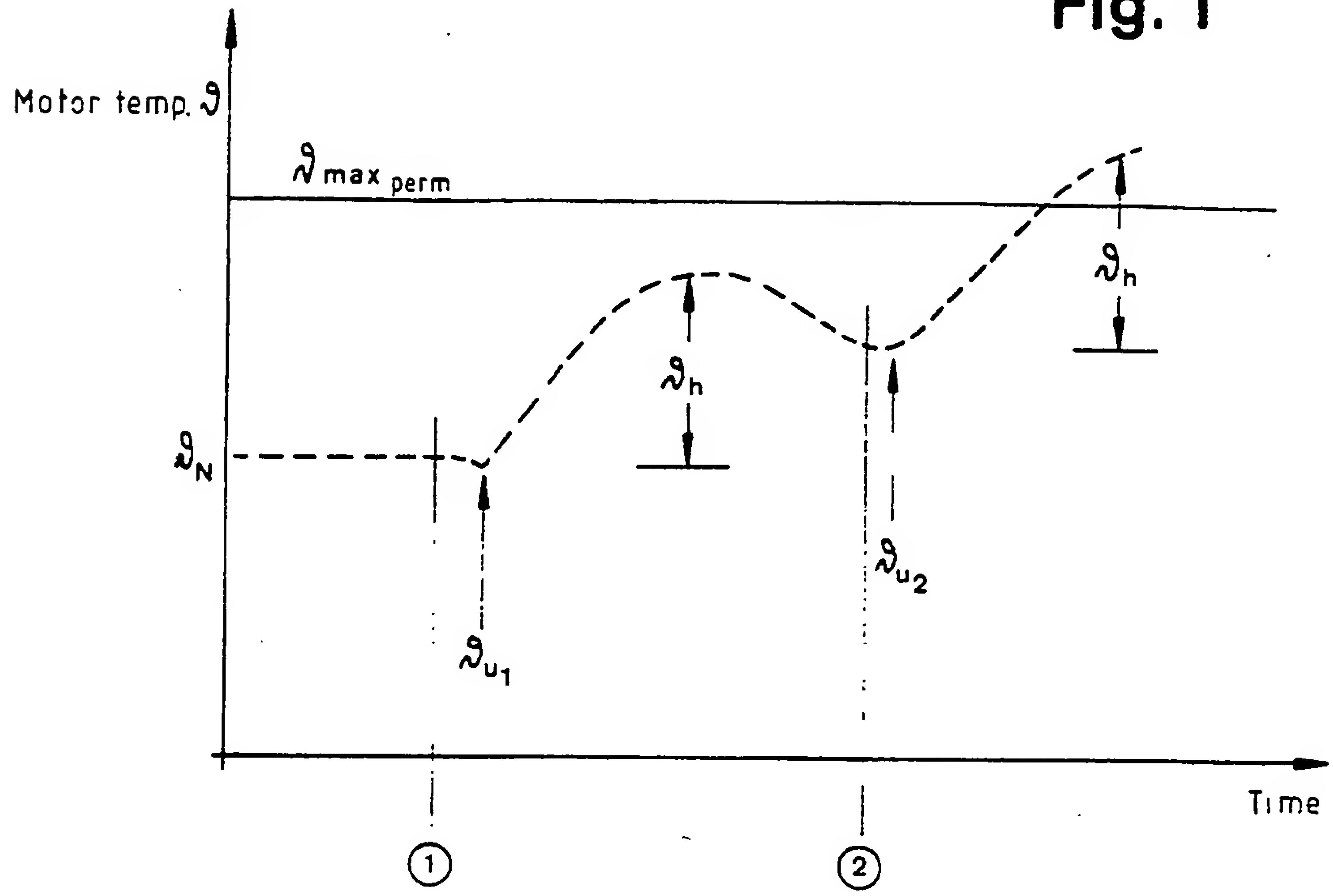
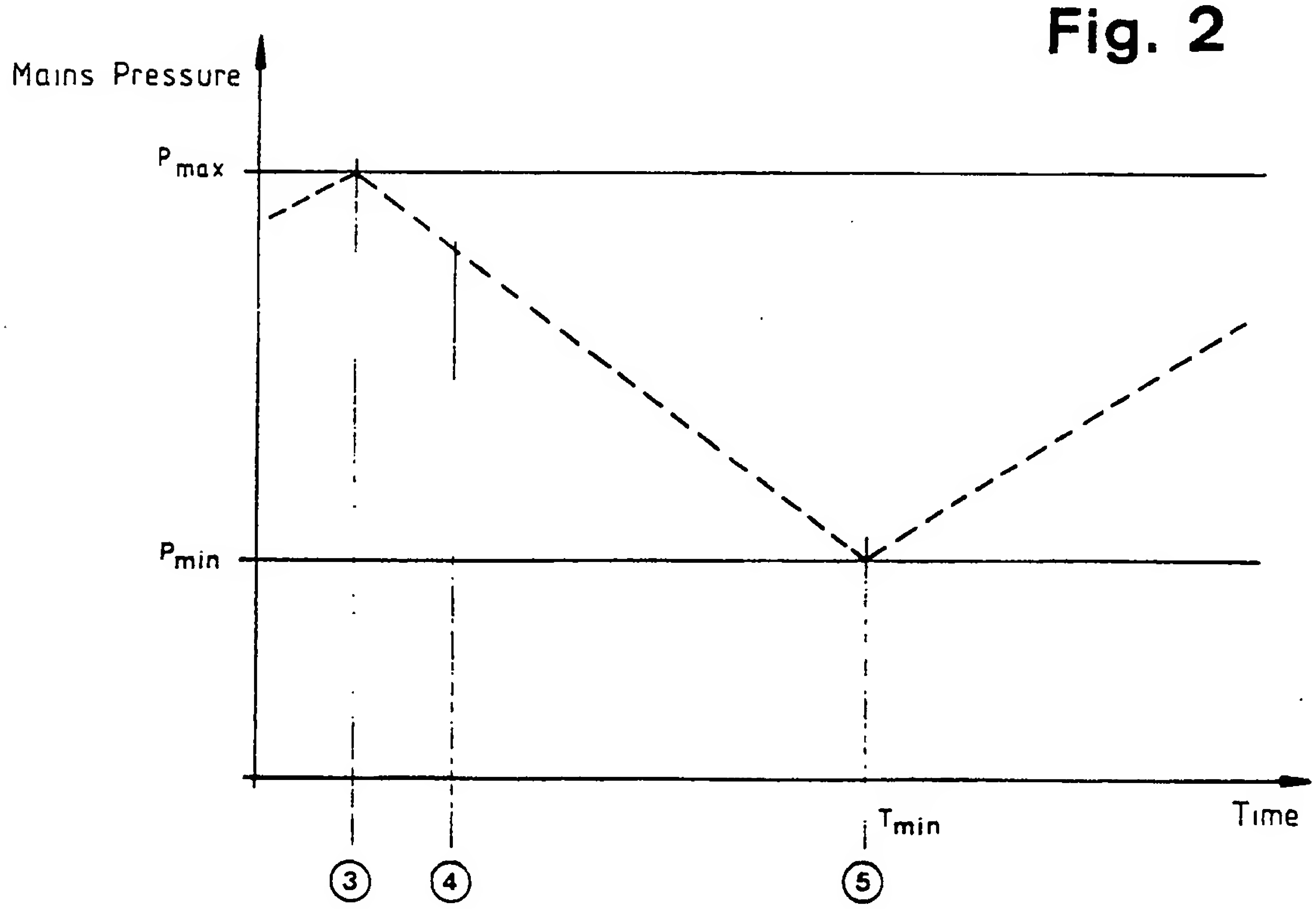

Motor temp. ϑ
$\vartheta_{max\ perm}$
ϑ_N
ϑ_h
ϑ_h
ϑ_{u_1}
ϑ_{u_2}
Time
1
2

Fig. 2


Mains Pressure
P_{max}
P_{min}
Time
T_{min}
3
4
5

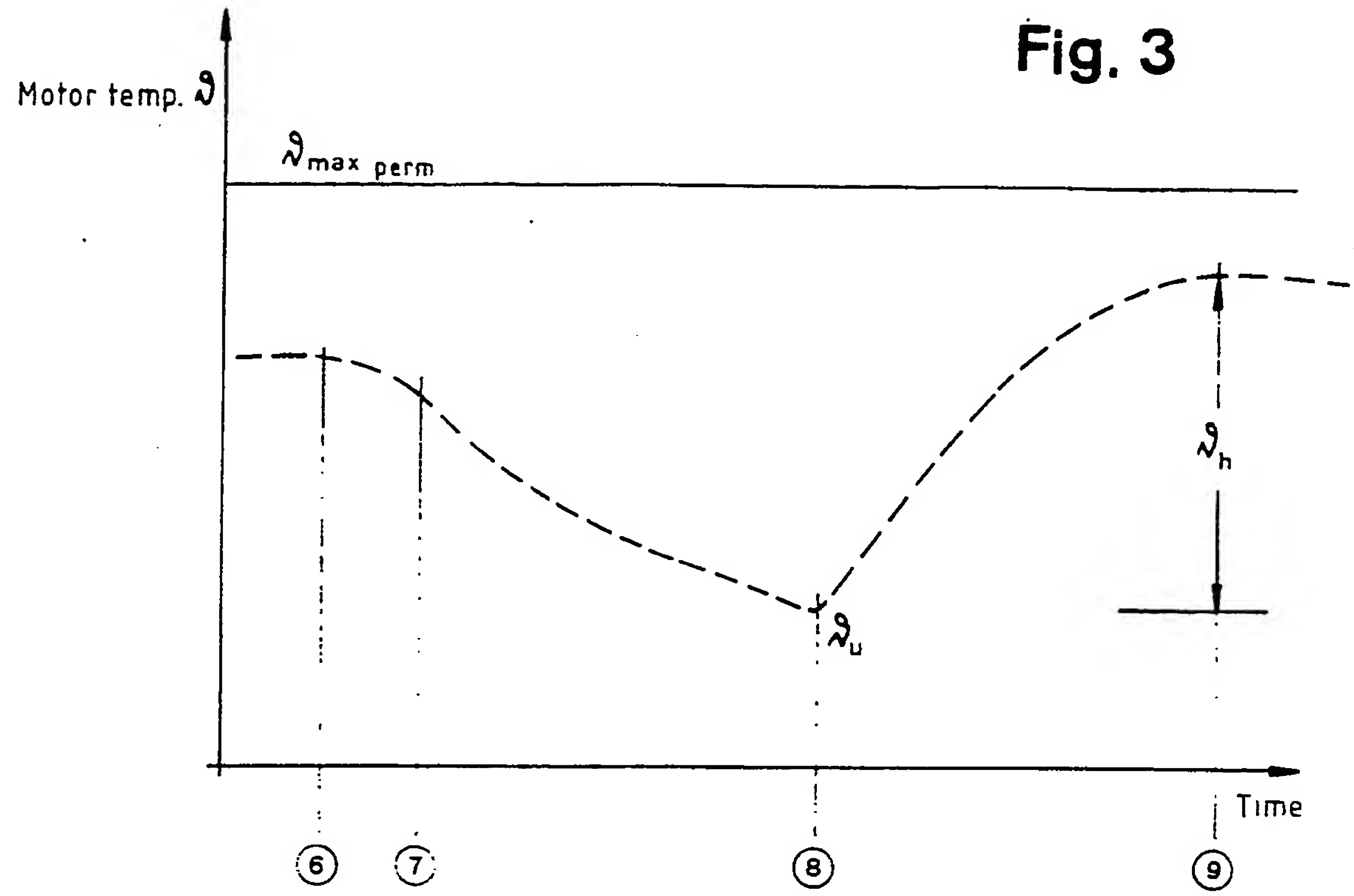

Motor temp. ϑ
$\vartheta_{max\ perm}$
ϑ_h
ϑ_u
Time
6
7
8
9

Fig. 3

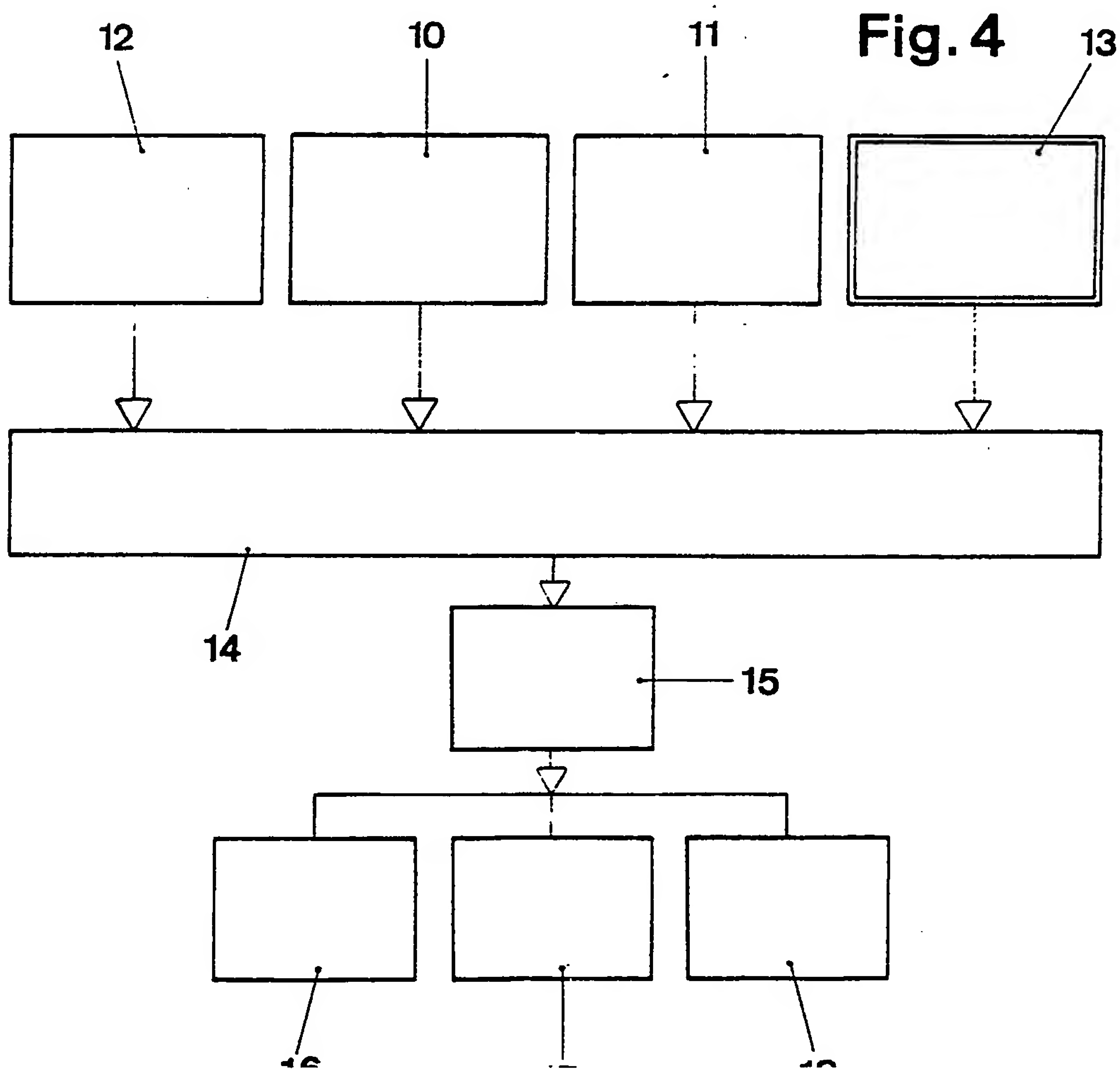

12
10
11
13
14
15

Fig. 4

METHOD AND EQUIPMENT FOR CONTROLLING OPERATION OF A COMPRESSOR

The present invention relates to a method and equipment for controlling operation of a compressor which in the case of changed compressed air demand is switched off (intermittent operation) or to idling (run-through operation) after reaching a given maximum pressure in its compressed air feed.

When a compressor provides more compressed air than is required at the time, the mains feed pressure rises to a maximum value. The compressor is then switched to intermittent operation until continuous operation is again required when the mains pressure has fallen to a minimum value.

Since the switching frequency of electric motors is limited in order to avoid increase of the motor temperature the compressor is switched to idling (run-through operation) in which it continues to run without load and conveys no compressed air, but still absorbs about one quarter of the full load performance.

In order to improve the economy of compressor operation in the case of load fluctuations, controls are used to decide between intermittent and run-through operation in dependence on the pressure decay to be expected and on the switching frequency of the drive motor preset by the motor manufacturer. It is also known for a compressor to automatically select the most favourable mode of operation, i.e. intermittent or run-through operation, through regulating equipment in dependence on air consumption during the intermittent operational state designated as conveying period. In that case, the duration of a conveying period is scanned by a timing relay. The compressor switches off when the maximum pressure is reached within the set time. However, if the maximum pressure is reached only after run-down of the timing relay,

then this corresponds to a relatively high air consumption so that the compressor is then switched to run-through operation. In that case, an induction throttle flap is closed and the installation is relieved of pressure.

The choice between the two operational modes is, as previously mentioned, dependent on the permissible switching frequency of the drive motor, which can be, for example, 4 to 6 switchings per hour.

The known controls have the disadvantage that the actual motor temperatures are not detected and evaluated, so that the compressor inevitably runs in idling operation more frequently than should really be necessary. In particular in the case of motors of high performance, this frequent idling operation represents a quite appreciable energy consumption.

There is therefore a need for a method for the control of a compressor, and corresponding control equipment, which may make it possible independently of the permitted motor swithcing frequency to determine the compressor motor actual temperature as a criterion for the choice between intermittent and run-through operation of the compressor.

According to a first aspect of the present invention there is provided a method of controlling operation of a compressor which in the case of changed compressed air demand is switched off or to idling after reaching a given maximum pressure in its compressed air feed, the method comprising the steps of measuring the value of the pressure in the feed and the value of the temperature of the compressor drive motor, evaluating the measured values, and switching off the motor on reaching of the maximum pressure if the evaluation indicates that the increase in motor temperature occurring on brief switching

off and subsequent switching back on of the motor will result in a temperature below a given maximum.

In a first alternative, however, the method may comprise switching the motor to idling on reaching of the maximum pressure if the evaluation indicates that the motor temperature increase occurring on brief switching off and subsequent switching back on of the motor will result in a temperature above a given maximum, and switching off the motor if and only if the temperature falls by such an amount that it will remain below the given maximum after subsequent brief running of the motor up to speed.

In a second alternative the method may comprise initially switching the motor to idling on reaching of the maximum pressure, determining the tendencies of pressure decay and decrease in motor temperature on switching of the motor to idling, calculating therfrom the instant at which a given minimum pressure in the feed will be reached and the motor temperature at that instant, and controlling the motor to idle or run intermittently in dependence on, respectively, whether the occurring increase in motor temperature will result in a temperature above or below a given maximum.

Accordingly, the method entails interrogating the temperature actually prevailing in the compressor drive motor, from which a decision is taken as to whether the compressor can be switched off in the case of low compressed air requirement without running the risk that the permissible motor temperature is exceeded in the case of a brief renewed switching-on because of increased compressed air requirement. The method may thus make possible an optimum adaptation of the compressor operation to the compressed air demand, a reduction in energy consumption

with reduced conveyed air quantity, a reduction in coolant costs and safe overload protection for the drive motor. Due to use of the criterion of motor temperature,the permissible switching frequency for the motor need not be exceeded even in the case of greatly fluctuating compressed air demand, and the idling times of the compressor may be minimised.

Preferably, an indirect current-measuring method is used for measurement of the motor temperature, for example by use of an electronic motor protection relay. This method is based on th principle that, in the case of a motor, the heating takes place from the energy converted as loss in the motor. In that case, the heating is dependent on the masses of copper and iron, the copper losses and the iron losses, the different thermal capacities and resistances, on the cooling conditions in different modes of operation, and on the supplied current.

Since these parameters are ascertainable in the case of a motor of known mode of construction, the heating of the motor can be derived as a function of the current through calculation or trial. The current measurement is possible by simple means in the feed line. Appropriate measuring devices are known fromthe evaluation for a motor type. The indirect current-measuring method can be carried out by simple devices currently available. The use of a direct measurement method may also be a feasible alternative.

Since the measurement of the actual motor temperature is utilised in the control method it may also be advantageous for the motor cooling to be independent of the compressor motor drive and, for example, for the motor cooling to be switched on only in case of need. This results in a power saving. On the other hand, the motor cooling can continue

for some time after switching off of the motor in order to lower the temperature level and in this manner to permit additional switching of the motor. Since the idling operation still requires about 35% of the full load power, whilst a cooling air fan may absorb only a few percent of the compressor power, this procedure may be advantageous in terms of energy-saving.

Even if this separation were possible in the case of the known compressor control methods the effect could not be utilised, since only the preset magnitude "permissible drive motor switching frequency" is employed as a switching-off criterion for the compressor.

According to second aspect of the present invention there is provided control equipment for controlling a compressor by the method of the first aspect of the invention, the equipment comprising switching control means for controlling operation of a drive motor and a load/idling regulator of the compressor, measuring means for measuring the value of the pressure in the compressed air feed of the compressor and the value of the temperature of the compressor drive motor, and a microprocessor to evaluate the measured values in relation to limit values and to provide a command signal for the control means in dependence on the evaluation result.

Examples of the method and an embodiment of the equipment will now be more particularly described with reference to the accompanying drawings, in which:

Fig. 1 is a temperature-time diagram relating to an example of the method of the present invention;

Fig. 2 is a pressure-time diagram relating to another example of the method;

Fig. 3 is a temperature-time diagram relating to the example of Fig. 2; and

Fig. 4 is a block schematic diagram of control equipment embodying the invention.

Referring now to the drawings there is shown in Fig. 1 a diagram in which the temperature of a compressor drive motor is entered on the ordinate and time T on the abscissa. Starting from an inertia temperature ϑ_N in load operation, a maximum compressed air pressure P_{max} is reached in the compressed air mains at the instant 1. If the starting temperature was the instantaneous temperature value ϑ_{u1}, the motor temperature would increase by the amount ϑ_h on brief renewed starting-up of the compressor drive, but the maximum permitted motor temperature $\vartheta_{max.perm.}$ would not yet be reached. The drive motor can thus be switched off.

The instant 2 indicates a state when P_{max} is reached in the mains. However, because of preceding switchings of the motor, the motor temperature would rise from the increased value ϑ_{u2} by the amount ϑ_h and thereby exceed the maximum permissible motor temperature. In this case, the compressor motor is not switched off, but runs at idle until $\vartheta_u + \vartheta_h$ is smaller than $\vartheta_{max.perm.}$.

In Fig. 2, the mains pressure is entered on the ordinate and time on the abscissa. The maximum mains pressure P_{max} is reached at the instant 3, and from the adjoining pressure decay tendency from instant 3 to instant 4 there is calculated the instant 5, designated T_{min}, at which a lower switching point for minimum pressure P_{min} will be reached.

In Fig. 3, as in Fig. 1 the motor temperature is entered on the ordinate and time on the abscissa. From the temperature levels at

instants 6 and 7 and the temperature decay tendency, the temperature ϑ_u at the instant 8, corresponding to the instant T_{min}, is calculated. It follows from the instant 9, where $\vartheta_u + \vartheta_h$ (ϑ_h = temperature rise on starting-up of motor) is smaller than $\vartheta_{max.perm.}$, that the drive motor can be switched off because the maximum temperature is not reached.

If, however, $\vartheta_u + \vartheta_h$ were greater than $\vartheta_{max.perm.}$, the compressor would continue to run in idling (run-through operation).

Fig. 4 shows control equipment in the form of a block schematic diagram, for carrying out a method exemplifying the invention. The two middle blocks of the upper row represent a device 10 for the constant detection of the motor temperature and a device 11 for constant detection of compressed air mains pressure. The signals issued by these devices are fed to the microprocessor 14, to which limit values of temperature and pressure are applied, as well as decision logic systems (arithmetic program), by way of an input terminal 13, for example a programming device. The microprocessor 14 processes the measurement values of the devices 10 and 11 according to initial settings of the input terminal 13 and derives commands which are issued to a compressor control unit 15. The control unit 15 switches a load/idling regulator 16, the compressor drive motor 17 and/or a cooling air fan motor 18 by way of switching devices (not shown).

In addition, the equipment can include a device 12 to supply signals concerning the operational state of the compressor, in particular load, idling or standstill of the compressor, to the microprocessor 14. The respective program is again applied by way of the input terminal 13. The microprocessor 14 ascertains the relationships between the compressor operational states and the drive motor temperature courses, in particular

the time behaviour of the motor temperature increase. The microprocessor stores this compressor behaviour occurring under target conditions as reference value and from this derives the corresponding decisions for the control unit 15, namely decisions for switching-over into load, idling, standstill and/or cooling air fan drive.

CLAIMS

1. A method of controlling operation of a compressor which in the case of changed compressed air demand is switched off or to idling after reaching a given maximum pressure in its compressed air feed, the method comprising the steps of measuring the value of the pressure in the feed and the value of the temperature of the compressor drive motor, evaluating the measured values, and switching off the motor on reaching of the maximum pressure if the evaluation indicates that the increase in motor temperature occurring on brief switching off and subsequent switching back on of the motor will result in a temperature below a given maximum.

2. A method of controlling operation of a compressor which in the case of changed compressed air demand is switched off or to idling after reaching a given maximum pressure in its compressed air feed, the method comprising the steps of measuring the value of the pressure in the feed and the value of the temperature of the compressor drive motor, evaluating the measured values, switching the motor to idling on reaching of the maximum pressure if the evaluation indicates that the motor temperature increase occurring on brief switching off and subsequent switching back on of the motor will result in a temperature above a given maximum, and switching off the motor if and only if the temperature falls by such an amount that it will remain below the given maximum after subsequent brief running of the motor up to speed.

3. A method of controlling operation of a compressor which in the case of changed compressed air demand is switched off or to idling

after reaching a given maximum pressure in its compressed air feed, the method comprising the steps of measuring the value of the pressure in the feed and the value of the temperature of the compressor drive motor, evaluating the measured values, initially switching the motor to idling on reaching of the maximum pressure, determining the tendencies of pressure decay and decrease in motor temperature on switching of the motor to idling, calculating therefrom the instant at which a given minimum pressure in the feed will be reached and the motor temperature at that instant, and controlling the motor to idle or run intermittently in dependence on, respectively, whether the occurring increase in motor temperature will result in a temperature above or below a given maximum.

4. A method as claimed in any one of the preceding claims, wherein the step of measuring each value comprises measuring by an indirect method.

5. A method as claimed in any one of the preceding claims, comprising the step of cooling the motor and maintaining such cooling while the motor is switched off and until the motor temperature has fallen to a predetermined value.

6. A method as claimed in any one of claims 1 to 4, comprising the step of cooling the motor and switching the cooling on and off independently of the operation of the motor but in dependence on the measured temperature value.

7. A method as claimed in either claim 1 or claim 2 and substantially

as hereinbefore described with reference to Fig.1 of the accompanying drawings.

8. A method as claimed in claim 3 and substantially as hereinbefore described with reference to Figs. 2 and 3 of the accompanying drawings.

9. Control equipment for controlling a compressor by the method as claimed in any one of claims 1 to 3, comprising switching control means for controlling operation of a drive motor and a load/idling regulator of the compressor, measuring means for measuring the value of the pressure in the compressed air feed of the compressor and the value of the temperature of the compressor drive motor, and a microprocessor to evaluate the measured values in relation to limit values and to provide a command signal for the control means in dependence on the evaluation result.

10. Equipment as claimed in claim 9, the switching control means being arranged to additionally control operation of cooling means for the motor.

11. Equipment as claimed in either claim 9 or claim 10, comprising input terminal means to apply the limit values to the microprocessor.

12. Equipment as claimed in claim 11, the input terminal means additionally being arranged to apply data indicative of the compressor operational state to the microprocessor, and the microprocessor being arranged to determine and store target relationships of motor

temperature behaviour and compressor operational state from such data and to use said relationships in evaluation of the measured values.

13. Equipment as claimed in claim 12, wherein the operational state data is indicative of at least one of the idling, standstill and load of the compressor motor.

14. Control equipment as claimed in claim 9 and substantially as hereinbefore described with reference to Fig. 4 of the accompanying drawings.